WHEN CAN WE AFFORD TO DEPLOY SOLAR FOR ON-GRID SOLUTIONS IN TELECOM?

David Wilson
Product Line Management, EMEA
Vertiv, Stockholm, Sweden

ABSTRACT

Multiple functions – Increasing Utility-Electrical Rates with lowering Energy (Solar) Costs - are influencing the decision of whether we should deploy solar for On-Grid Solutions. In this study, with a set of simulations, we look at what at the current considerations that can justify deploying Solar for On-Grid sites.

INTRODUCTION

Solar Panels and Converters are typically used in Telecom Applications, as an Energy Source to support and-or compliment battery recharging for Off-Grid sites. As such, it is an energy device, whose purpose is to charge the battery that serves the load.

With the reduction of solar panel prices and infrastructure, and the slow rise of utility rates, can solar serve as a power device and share duties to provide power to the load in On-Grid solutions with reasonable financial returns to justify this expenditure. If the opportunity is feasible, what are the functions that defines solar as a viable solar power source?

With several simulations across a vast network, opportunities to start planning and implementing solar as a power device are emerging, where solar converters may share duties with the traditional rectifier and grid connection, we will illustrate that solar can be an effective financial solution once the cost of power exceed 0.25 USD/kWh.

ASSUMPTIONS AND TOOLS

A. General

1. Currency is in USD ($), unless noted otherwise.
2. Load for Simulation, unless stated otherwise, is 3KW.
3. Solar Array, unless stated otherwise is 4KW.
    a. For Stable-On-Grid Solutions, maximum Payback and ROI is achieved where solar array output is less than the load, so as all power is delivered.

       The associated consequence, the solar array will never assume full responsibility to support the load.
4. Solar Array Tilt selected is from a set of 4 angles, 12°, 22° 32° and 52°, which-ever produced the maximum annual solar production.
5. Solar Array set to best polar Azimuth (0° or 180°) to maximum best annual solar production.

B. Utility Rate and Datasets

Utility Rates are presented in USD/kWh, unless otherwise stated.

Utility Rates used, unless state otherwise reflect World Bank reporting for 2017 for each country. Experience has proven this stated value is often a rate lower than the burden the carrier absorbs, once all costs – taxes, distribution – and local variances are applied. For example, in Botswana, the listed rated at the World Bank is 0.118, but actual rates are known to vary from 0.07 to 0.180.

Similarly, in the United States actual ranges seen in 2015 were from 0.067 to 0.35; while in Jordan rates experienced vary from 0.20 to 0.40, with the World Bank reporting 0.245.

Complex Utility rates, where costs may be structure on Time Of Use and Load Peaks, was not considered.

C. Countries Studied and Associated Utility Rate

33 Countries reviewed utilizing 70 TMY (Solar Typical Meteorological Year) datasets. Prior experience with global solar radiation maps were used to select representative, and a few extremes.

Table 1: Countries, Utility Rates and Typical Annual Energy Available to be Delivered to the Load

COUNTRY	RATE $/KWH	ANNUAL KWH
Botswana	0.118	25,021
Burkina Faso	0.254	21,449
Cameroon	0.157	20,280
Central Africa Rep	0.110	17,186
Cote d'Ivorie	0.139	15,602
Croatia	0.162	12,938
DRC - Congo	0.25*	16,108
Egypt	0.109	24,496
Equatorial Guinea	0.233	15,491
France	0.145	12,351
Guadeloupe	0.239	21,065
Guinea	0.164	20.396
Guinea Bissau	0.276	20.396
Iraq	0.143	20,696
Jordan	0.245	24,381
Liberia	0.556	17,485
Luxembourg	0.127	12,001
Madagascar	0.131	17,034
Mali	0.153	22,252
Manutius	0.246	20,062
Moldova	0.105	13,629
Morocco	0.128	22,033
Niger	0.236	22,239
Poland	0.151	11,633
Romania	0.085	13,922
Senegal	0.213	20,307
Sierra Leone	0.259	18,395
Slovakia	0.143	13,246
Spain	0.159	19,113
Sweden	0.120	11,675
Tunisia	0.096	23,618
Vanuata	0.338	18,923
Western Sahara	0.25*	21,702

* Of these two countries. DRC and Western Sahara, the World Bank did not have an operating profile to use, and a default value was used, if presented.

D. Cost of Solar

This simulation reflects the cost of adding solar to an existing solution – converters, cables, frames, solar panels with the following price table. It does not include cost to install or cost of any real-estate costs.

The price table reflects a budgetary cost of a ground mount solar frame supporting a moderate wind load of 45m/s supplied from the EU in low volumes. Opportunities for price improvement are real.

Table 2: Capital Cost of Solar as a Function of Size

SOLAR ARRAY SIZE (KW)	COST ($)
2	2524
4	4462
6	7035
8	8965

E. Simulation Tool

Refer to Figure 1 and Figure 2.

The simulation tool is based on hourly TMY (Typical Meteorological Year) data as provided by Meteonorm, with a projected 20.1% losses from array to load, as a function of dirt, aging, wire-line losses, et cetera into a 2000W Converter using 8 Mono-Crystalline Panels connected in series.

The use of an hourly TMY model was selected for its accuracy and precision to truncate power delivery, when an array's power exceeds the load's need. Thus, not over-estimating the array's contribution to lowering operating cost.

The solar panel has a listed efficiency of 17.1%, STC Performance of 280W, a Power Drop of -0.39%/K and a NOCT listing of 209W.

1. Input:

- Location of TMY Model – Identifier, then Latitude and Longitude.
- Load.
- Solar Array into a 2KW Converter:
  - Size – defined by the number of 2KW Converters
  - Framing Geometry – Tilt and Azimuth
  - Losses – Standard and Shade
- Utility Cost.
- Utility Generation Energy Source.

2. Output:

- Monthly Summary of Energy Demand, as a function of load.
- Monthly Summary of Solar Energy, as a function of solar array and location.
  - Data is also plotted to see how averages are differentiate by Month and Load.
- Monthly Summary of Energy reduced from the Grid.
  - Calculations are based on hourly power calculation, where over power production is truncated to the load.
- Monthly Cost and Savings – monetary and GHG (Green House Gases).
- Financial Calculations – Cost of Array, Annual Savings, Payback and ROI.

Figure 1: Illustration of Simulation Tool Output for Vanuata

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On-Grid Solar Model for Vanuata (-14.9, 166.6)

Solar Configuration and Performance

Location (Lat, Lon):	Vanuata (-14.9, 166.6)	
Average Site Load:	3.000	kW
Solar Panels:	290+W Mono+PERC - RYZ902020/3	
Frame Tilt:	12	Standard =12, 22, 32
Azimuth (0=North):	0	0=Array Pointing North
Shade Impact:	0%	
Planned Losses:	20.1%	Dirt, Aging & Efficiency
Number of S48 Converters:	5	10kW Solar Array
Max Solar to Load Ratio:	3.333	
Currency:	$	
Solar Solution Price:	11514	$
Utility/Energy Cost:	0.338	$/kWhr
Primary Utility Energy Source:	Diesel	
Utility GHG Emissions:	0.778	kg/kWhr

Model Tool: Vertiv - Meteonorm - 20170707

Power - Demand versus Solar Available and Delivered

	Demand (kWhr)	Solar Energy (kWhr) Available	Solar Energy (kWhr) Delivered		Savings $	
January	2160	1486	857	58%	290	40%
February	1944	1509	801	53%	271	41%
March	2160	1659	864	52%	292	40%
April	2088	1140	710	62%	240	34%
May	2160	1328	796	60%	269	37%
June	2088	1266	753	59%	254	36%
July	2160	1088	703	65%	238	33%
August	2160	1121	715	64%	242	33%
September	2088	1490	824	55%	278	39%
October	2160	1603	882	55%	298	41%
November	2088	1421	820	58%	277	39%
December	2088	1552	858	55%	290	41%
Annual	25,344	16,662	9,583	58%	**3,239**	**38%**

GHG Reduction: 7.456 tonnes/year

Primary Source	GHG kg/kWhr
Hydroelectric - River	0.013
Hydroelectric - Tidal	0.010
Nuclear	0.066
Biogas	0.011
Biomass	0.025
Natural Gas	0.443
Diesel	0.778
Heavy Oil	0.778
Coal	0.960
Solar PV	0.032
Wind	0.010
Geothermal	0.038
Default Unknown	0.400
User Defined	0.500

Financial Performance

Payback Period (Year(s)) 3.6

Year	Financial Performance	Saving	ROI
1	Savings-ROI after 1 year(s)	-8275 $	-72%
2	Savings-ROI after 2 year(s)	-5036 $	-44%
3	Savings-ROI after 3 year(s)	-1797 $	-16%
5	Savings-ROI after 5 year(s)	4682 $	41%
7	Savings-ROI after 7 year(s)	11160 $	97%
10	Savings-ROI after 10 year(s)	20877 $	181%

Average Solar Power Available by Hour vs Load

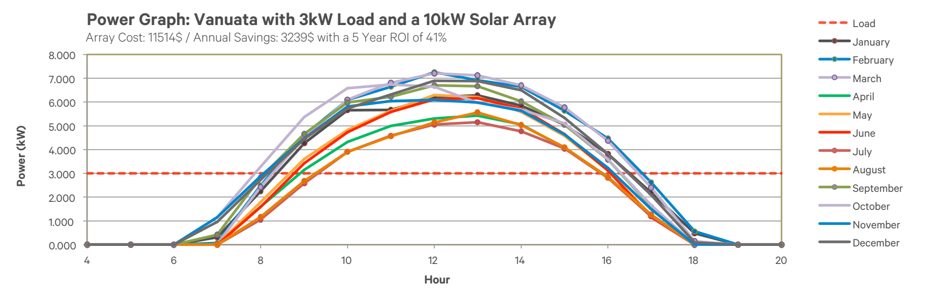


Figure 2: Illustration of Simulation Tool Output for France 6KW Array for 3KW Load

VERTIV.

On-Grid Solar Model for France (48.7, 3.4)

Solar Configuration and Performance

Location (Lat, Lon):	France (48.7, 3.4)	
Average Site Load:	3.000	kW
Solar Panels:	290+W Mono+PERC - RYZ902020/3	
Frame Tilt:	12	Standard =12, 22, 32
Azimuth (0=North):	180	0=Array Pointing North
Shade Impact:	0%	
Planned Losses:	20.1%	Dirt, Aging & Efficiency
Number of S48 Converters:	3	6kW Solar Array
Max Solar to Load Ratio:	2.000	
Currency:	$	
Solar Solution Price:	7035	$
Utility/Energy Cost:	0.150	$/kWhr
Primary Utility Energy Source:	User Defined	
Utility GHG Emissions:	0.230	kg/kWhr

Model Tool: Vertiv - Meteonorm - 20170707

Power - Demand versus Solar Available and Delivered

	Demand (kWhr)	Solar Energy (kWhr) Available	Delivered		Savings $	
January	2160	150	150	100%	23	7%
February	1944	245	239	98%	36	12%
March	2160	488	460	94%	69	21%
April	2088	760	670	88%	100	32%
May	2160	871	719	82%	108	33%
June	2088	898	761	85%	114	36%
July	2160	911	791	87%	119	37%
August	2160	761	686	90%	103	32%
September	2088	611	559	92%	84	27%
October	2160	389	378	97%	57	17%
November	2088	198	198	100%	30	9%
December	2088	94	94	100%	14	5%
Annual	25,344	6,377	5,706	89%	**856**	**23%**

GHG Reduction: 1.312 tonnes/year

Primary Source	GHG kg/kWhr
Hydroelectric - River	0.013
Hydroelectric - Tidal	0.010
Nuclear	0.066
Biogas	0.011
Biomass	0.025
Natural Gas	0.443
Diesel	0.778
Heavy Oil	0.778
Coal	0.960
Solar PV	0.032
Wind	0.010
Geothermal	0.038
Default Unknown	0.400
User Defined	0.500

Financial Performance

Payback Period (Year(s)) 8.2

Year	Financial Performance	Saving	ROI
1	Savings-ROI after 1 year(s)	-6180 $	-88%
2	Savings-ROI after 2 year(s)	-5324 $	-76%
3	Savings-ROI after 3 year(s)	-4468 $	-63%
5	Savings-ROI after 5 year(s)	-2756 $	-39%
7	Savings-ROI after 7 year(s)	-1044 $	-15%
10	Savings-ROI after 10 year(s)	1525 $	22%

Average Solar Power Available by Hour vs Load

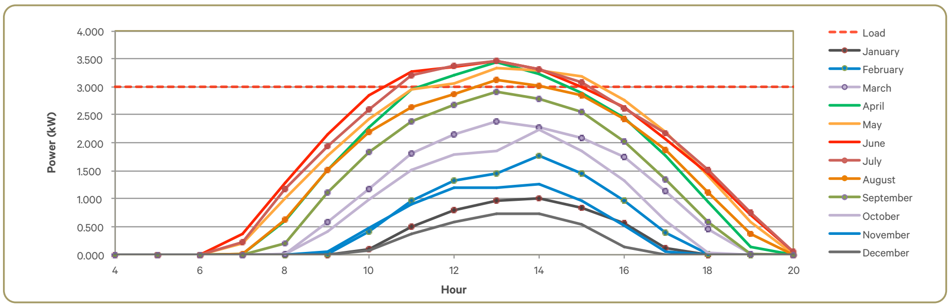
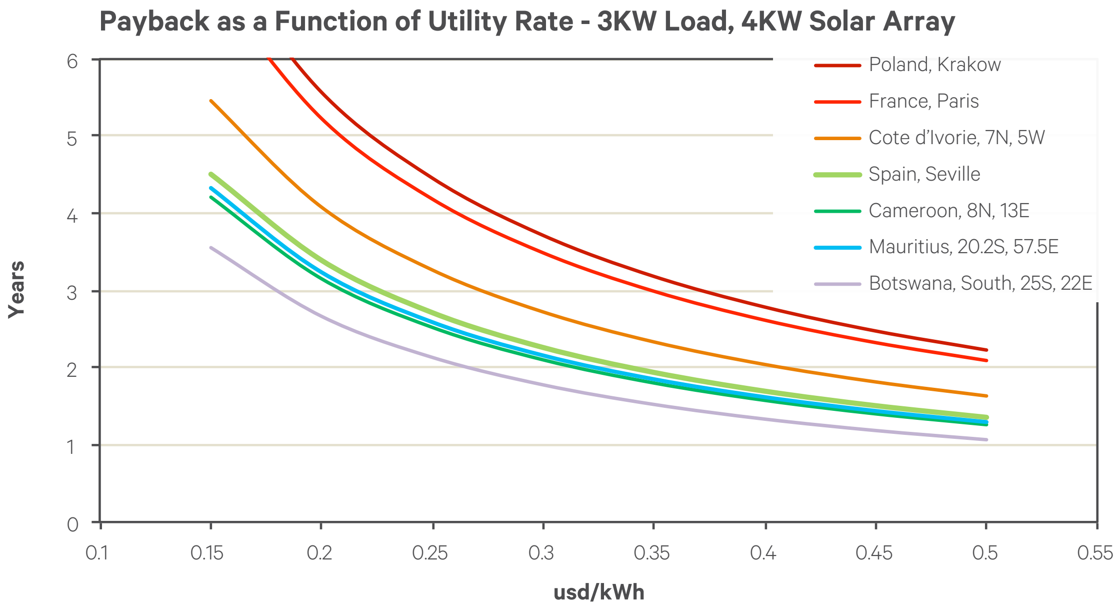


Table 3: Countries, Utility Rates and Typical Annual Energy Available to be Delivered to the Load

REPRESENTATIVE	COUNTRY, SITE	PAYBACK PERIOD AS A FUNCTION OF UTILITY RATES - YEARS							
		0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5
Minimum Site	Poland, Krakow	7.42	5.57	4.46	3.72	3.18	2.79	2.48	2.23
Central Europe	France, Paris	6.97	5.23	4.19	3.49	2.99	2.62	2.33	2.09
Equatorial Africa	Cote d'Ivorie: 7N, 5W	5.45	4.08	3.27	2.72	2.33	2.04	1.82	1.63
Southern Europe	Spain, Seville	4.52	3.39	2.71	2.26	1.94	1.70	1.51	1.36
Tropical Island	Mauritius: 20.2S, 57.5E	4.32	3.24	2.59	2.16	1.85	1.62	1.44	1.30
Central Africa	Cameroon: 8N, 13E	4.21	3.15	2.52	2.10	1.80	1.58	1.40	1.26
Northern Africa	Egypt, South: 22N, 32E	3.59	2.69	2.15	1.80	1.54	1.35	1.20	1.08

Graph 1: Payback for Reference Locations, as a Function of Utility Rate



PAYBACK AS A FUNCTION OF UTILITY RATE

As illustrated in Table 3 and Graph 1, in bright annual solar regions, if Utility Costs Rate is greater than 0.25 a reasonable return is possible. As we migrate to locations with greater seasonal impact, such as those seen in Europe, rates must rise to 0.35 before a reasonable rate of return is possible.

UTILITY RATE REQUIRED TO ACHIEVE A 3 YEAR PAYBACK AT THE REPRESENTATIVE LOCATIONS

Refer to Tables 4 and 5.

At sites with a high burden Utility (electrical) rate, the use of solar site can provide a reasonable financial benefit, and substantiates the trend, that solar is emerging as a financial solution as a supporting power device.

Table 4: Countries, Utility Rates and Typical Annual Energy Available to be Delivered to the Load

SITE		UTILITY RATE	
		ACTUAL	REQUIRED FOR 3 YEAR PAYBACK
Minimum Site	Poland, Krakow	0.151	0.37
Central Europe	France, Paris	0.145	0.35
Equatorial Africa	Cote d'Ivorie: 7N, 5W	0.139	0.27
Southern Europe	Spain, Seville	0.159	0.23
Tropical Island	Mauritius: 20.2S, 57.5E	0.246	0.22
Central Africa	Cameroon: 8N, 13E	0.157	0.21
Northern Africa	Egypt, South: 22N, 32E	0.109	0.18
Maximum Site	Botswana, South: 25S, 22E	0.118	0.18

Table 5: Financial Performance Summary of Representative Sites

SITE		ANNUAL			PAYBACK	ROI	
		ENERGY	SAVINGS				
		KWH	$	%	YEARS	3YR	5YR
Minimum Site	Poland, Krakow	11,633	605	16%	7.375	-59%	-32%
Central Europe	France, Paris	12,109	618	17%	7.219	-58%	-31%
Equatorial Africa	Cote d'Ivorie: 7N, 5W	12,938	759	22%	5.879	-49%	-15%
Equatorial Africa	Equa. Guinea, 1.5S, 10.3E	15,491	1262	21%	2.582	-15%	42%
Equatorial Africa	Guinea Bissau, 12N, 15.1E	17,880	1728	25%	2.582	16%	94%
Southern Europe	Spain, Seville	19,113	1046	26%	4.265	-31%	7.2%
Tropical Island	Mauritius: 20.2S, 57.5E	20,062	1695	27%	2.633	14%	90%
Central Africa	Cameroon: 8N, 13E	20,820	1111	28%	4.016	-50%	25%
Northern Africa	Egypt, South: 22N, 32E	24,496	903	33%	4.941	-39%	1%
Maximum Site	Botswana, South: 25S, 22E	25,021	987	33%	4.521	-34%	11%

Table 6: What is the Gap in Solar Costs to Meet a 3 Year Payback, Assuming all other Variables are Constant

SITE		COSTS ($)					
			TODAY		FUTURE - FOR 3 YEAR PAYBACK		
		UTILITY	ARRAY	/W	ARRAY	/W	CHANGE
Minimum Site	Poland, Krakow	0.151	4462	1.115	1815	0.454	-59%
Central Europe	France, Paris	0.145	4462	1.115	1854	0.464	-58%
Equatorial Africa	Cote d'Ivorie: 7N, 5W	0.390	4462	1.115	2277	0.569	-49%
Equatorial Africa	Equa. Guinea, 1.5S, 10.3E	0.233	1262	1.115	3786	0.947	-15%
Equatorial Africa	Guinea Bissau, 12N, 15.1E	0.276	4462	1.115	5184	1.296	16%
Southern Europe	Spain, Seville	0.159	4462	1.115	3138	0.785	-30%
Tropical Island	Mauritius: 20.2S, 57.5E	0.246	4462	1.115	5085	1.271	14%
Central Africa	Cameroon: 8N, 13E	0.157	4462	1.115	3333	0.833	-25%
Northern Africa	Egypt, South: 22N, 32E	0.109	4462	1.115	2708	0.677	-39%
Maximum Site	Botswana, South: 25S, 22E	0.118	4462	1.115	2960	0.740	-34%

A. Table 5 Site Expansion of Sites defined

As Equatorial Africa – which covers parts of West Africa, Central Africa and East Africa – is approaching the break point of being a viable solution today – given its higher annual solar resources and variable electric costs – the sites listing was expanded.

COST OF SOLAR

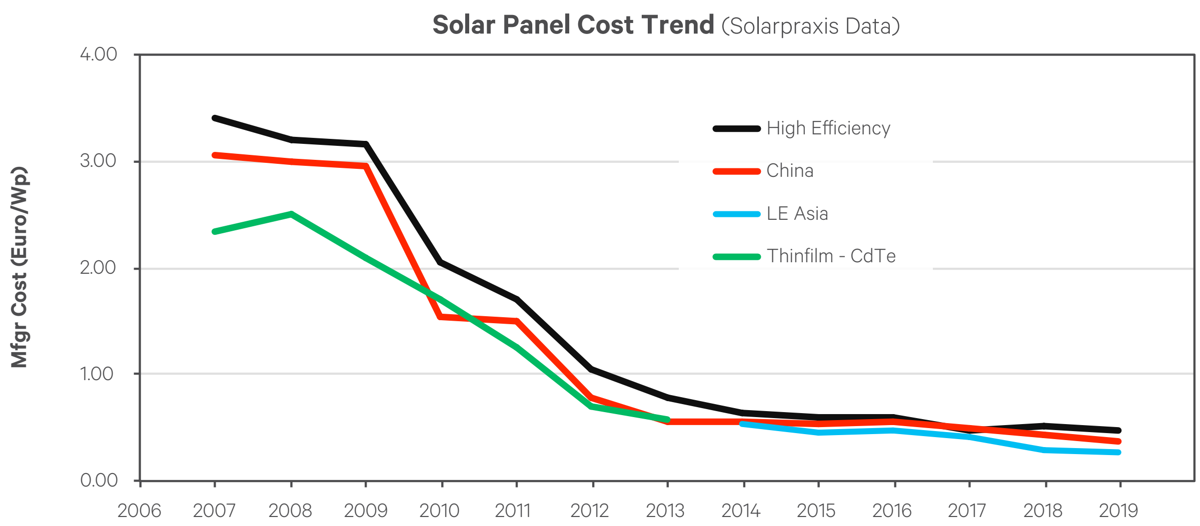
Refer to Graphs 2 and 3.

Cost of solar has decreased, and expected to continue to decrease, but there are no forecast large drops. Though lowering of solar panel pricing will continue, the primary industry focus has been shifting to address BOS (Balance of System Costs), arranging from solar frames to site acquisition and land management cost.

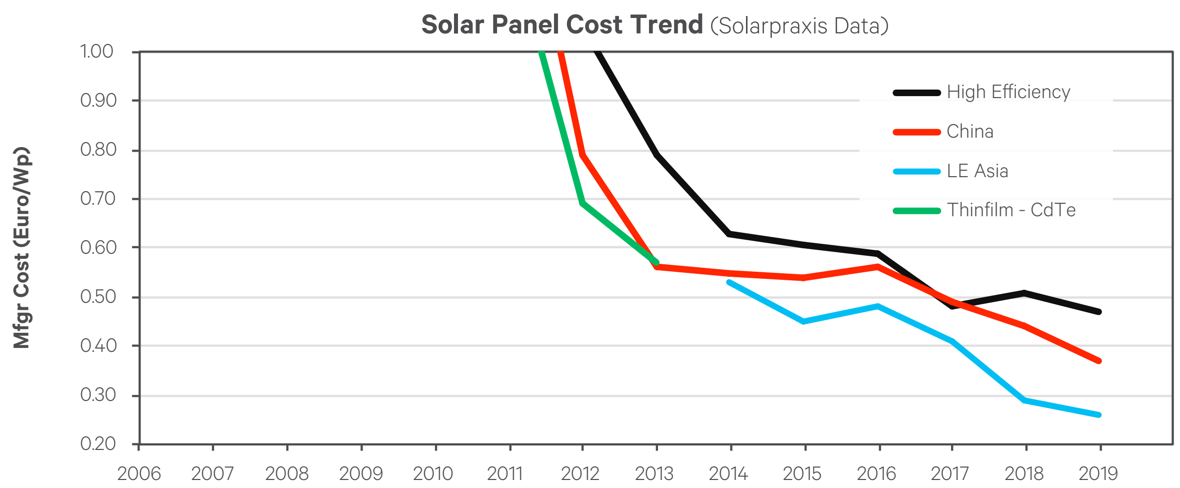
Refer to Table 4.

The cost reductions required to achieve the short term financial goals that are typically desired, may be within reasonable reach in the near future, if the utility rates are high, but it is unlikely solar costs reductions alone will enable solar as a power device.

Graph 2: Solar Panel Cost Trend - Long View

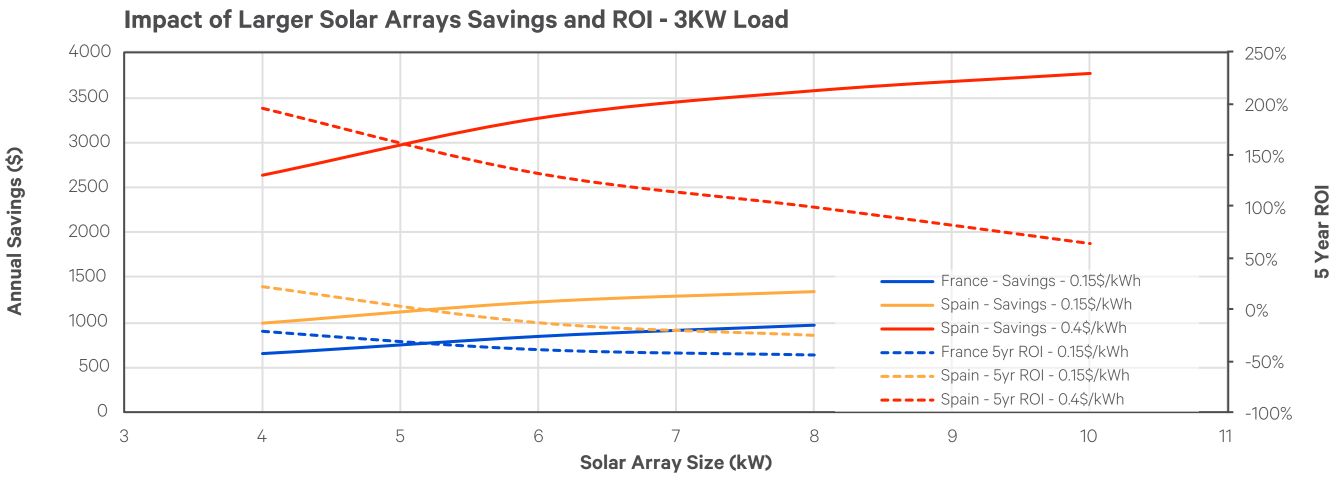


Graph 3: Solar Panel Cost Trend – Focus on Last 3 Years



ROI OR SAVINGS

Graph 4: ROI Versus Savings



As we noted in the assumptions, the condition for best for financial performance, when measured as a function of ROI, is to ensure all power available is delivered to the load, or the solar array output is less than the drain from load and any float battery charging. The inherent function outcome of this financial restriction, the rectifiers are always present, such that they cover the gap between the solar converter output and the load demand.

Refer to Graph 5 where the Array was configured for best ROI for Spain at current utility rates of 0.159$/kWh, providing a 5-year ROI of 17% and an annual savings of 1046$. The array is expected to be able to deliver 98% of its capacity to the load.

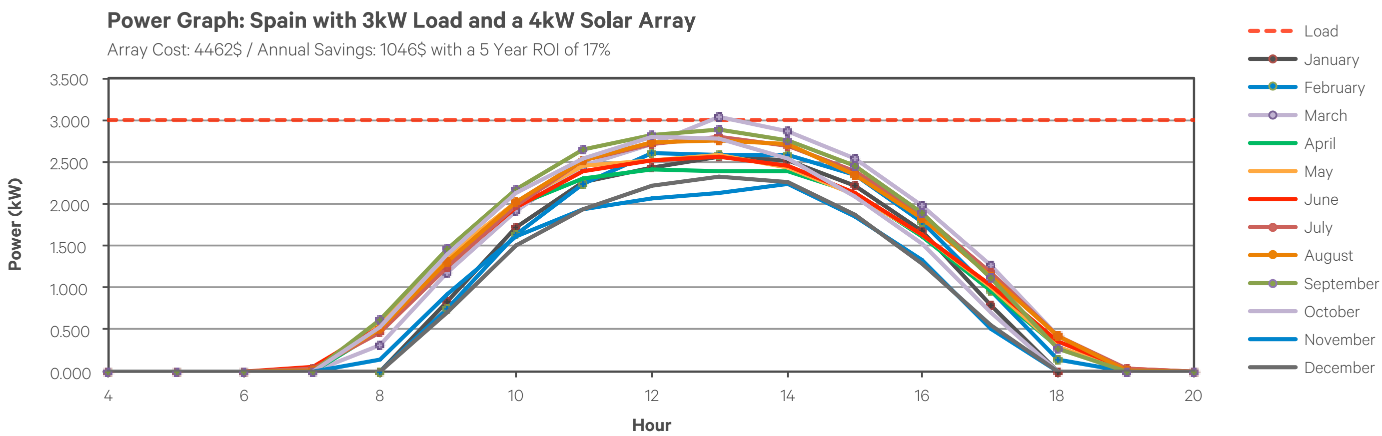
More solar can be added and even support the load, that will increase the savings, but because of the array is not fully utilized, its financial performance, as a function of ROI or Payback, will decrease. The savings will increase, but not the true financial performance.

Refer to Graph 6 where the Array was configured to enable the rectifiers to go offline during the day. The 5-year ROI will drop to -8% (drop by 25 points), though the annual savings to 1299$.

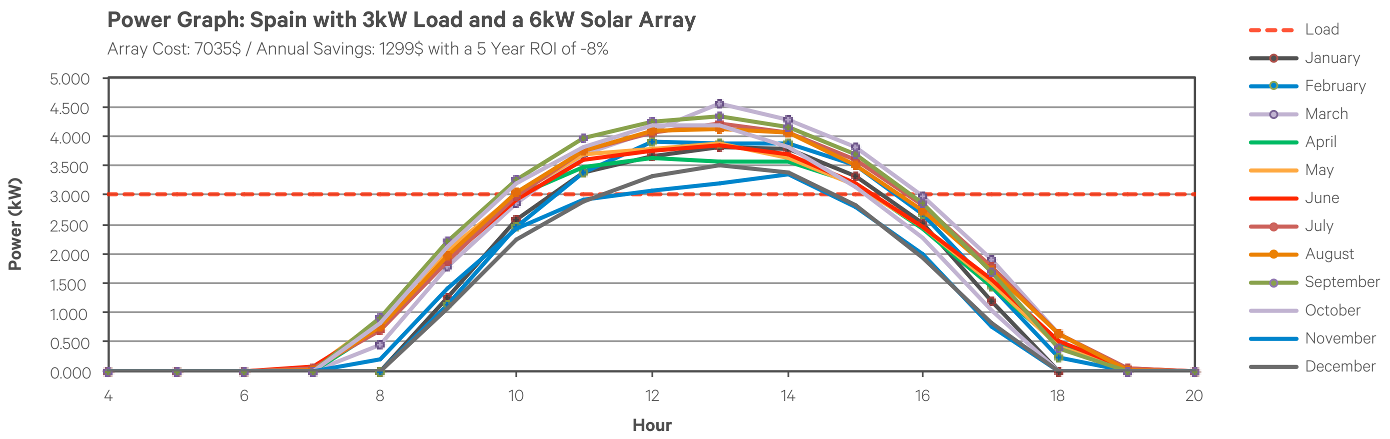
A. Can a best savings solution be justified?

If the objective is singular, provide the best ROI and Payback, the simple answer is no.

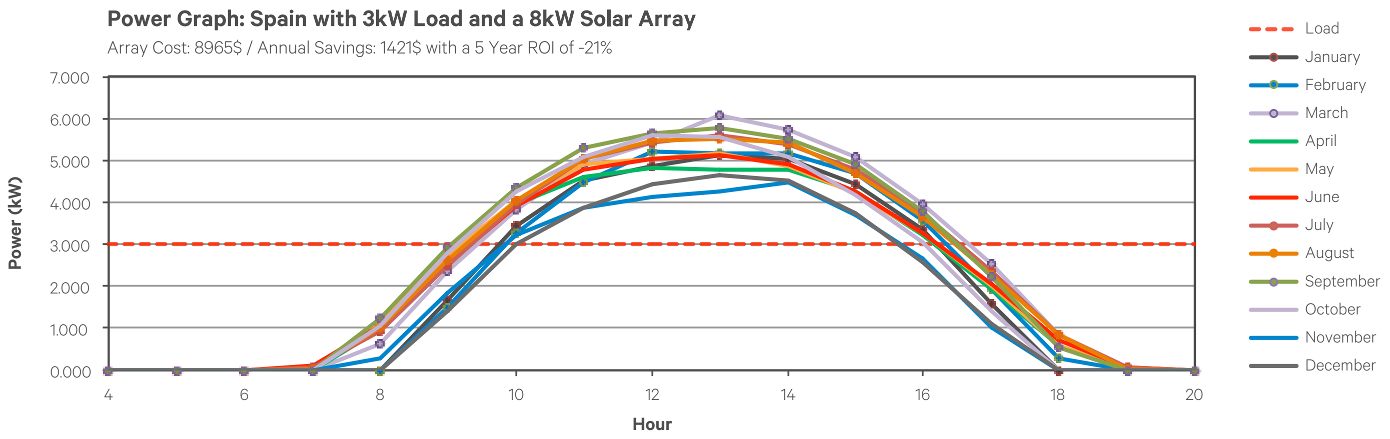
Graph 5: Spain, Selville Solution Configured for ROI



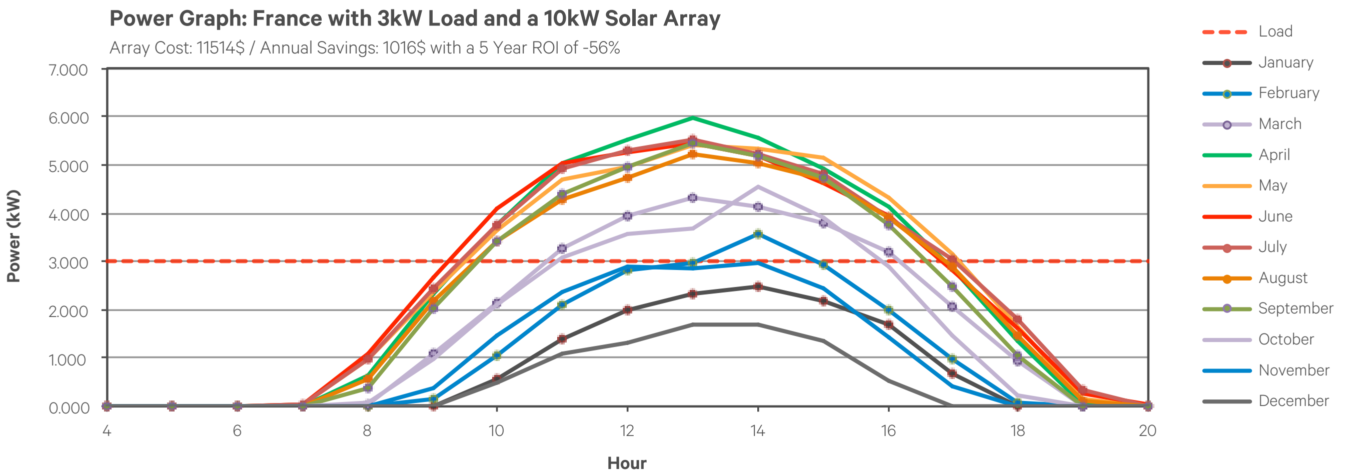
Graph 6: Spain, Selville Solution Configured for Savings



Graph 7: Spain, Selville Solution Configured for Keeping Rectifiers Off During the Day



Graph 8: France, Paris Configured for Keeping Rectifiers Off During The Day – April to September



Never-the-less there remains two conditions, that can warrant a solution that is based on a reduced ROI – Bad-Grid and High Utility Cost.

As demonstrated in the simulation for Spain, refer to Graph 4, if the utility rate is high, such as 0.40$/kWh (red line), an increase operating savings can be achieved while maintaining a positive ROI. The decision the lies with the business, what is the financial objective? And can you comprise on the ROI to increase annual savings, in a world where you expect utility rates too rise.

In a Bad-Grid solution, where the primary objective is to maintain power and service without accelerating the replacement schedule-cost of batteries, the solar array can be an effective financial tool that reduces stress on the operational cost of managing a battery plant.

CONCLUSION

Most developed nations have taken the effort to provide low electrical utility rates, as a lever to provide business and the community, an environment that is conducive to growth. Never-the-less, at the fringes of a power network or countries that need to import energy can be subjected to high costs, id est rates above 0.25$/kWh. In these conditions, deploying solar as a power device is a reasonable tool to manage operating costs of a telecom network.

VertivCo.com | **Vertiv Infrastructure Limited,** George Curl Way, Southampton, SO18 2RY, VAT Number: GB188146827